Monsoon Disturbances Over Southeast and East Asia and the Adjacent Seas

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LONG TERM GOALS

To study weather disturbances over the Southeast and East Asian monsoon region and its adjacent seas using Navy research and operational analysis and forecast models. The primary goal is to advance the understanding of the weather-producing systems in the region, in order to improve forecast capabilities. In the process we will assess the skill and characteristics of the models in representing and forecasting these disturbances, and find clues that may be useful for model improvement efforts.

OBJECTIVES

The objectives are to study the structure and the dynamic and thermodynamic properties of the synoptic and meso- scale weather-producing disturbances in the Southeast and East Asian monsoon region, the South and East China Seas, and the western Pacific and the eastern Indian Ocean. The key questions to be answered are the development and evolution mechanisms of these disturbances and their interactions with the different stages of the large-scale monsoons in the atmosphere and ocean. The study covers both the summer monsoon and the winter/Austalian monsoon. In northern summer the focus is on the convective "Mei-yu" disturbances ("Changma" in Korea and "Baiu" in Japan) that developed following the onset and reinforcement of the southwest monsoon in the South China Sea. In northern winter the focus is on the convective systems in the vicinity of the equatorial trough near the maritime continent, where tropical intraseasonal and synoptic scale disturbances, as well as cold surges, may contribute to strong convection leading to tropical cyclone development. This work is supported by ONR Marine Meteorology.

APPROACH

Observational studies/Data analysis: Use archived gridded data from global NWP outputs and satellite data to determine the structure of mesoscale and synoptic disturbances in various local regions. Use composite and principal component approaches to perform statistical analysis of the data.

Numerical modeling: Perform sensitivity and simulation studies of the observed monsoon disturbances with Navy's regional research and operational models. In FY 99 we are transitioning from NORAPS to COAMPS. Models initialized with Navy and ECMWF global fields. The sensitivity studies look at both impacts of enhanced radiosonde data reports, the effects of topography and diabatic heating, and the satellite scatterometer data. The results are analyzed with vorticity and vertical motion diagnostic tools.

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WORK COMPLETED

A diagnostic study that used the GMS water vapor IR data, NCEP 1000 hPa wind reanalysis, and NSCAT surface wind data to examine the evolution among several large-scale transient motions in the tropical convection region of the northern winter (southern summer) monsoon during December 1996 – March 1997. This region includes the areas surrounding the maritime continent, South China Sea, northern Australia and the equatorial West Pacific. The purpose is to study the possible interactions among these motions in general, and the resultant effects on the development of tropical cyclones in particular.

To prepare for the numerical modeling studies, we began the installation and testing of COAMPS at NPS and DoD computers, and the processing and format conversion from the operational NOGAPS analysis and forecast fields to produce the initial and boundary condition data for experiments to be conduted over the SCSMEX period (May and June 1998) and region.

RESULTS

1. Diagnostic studies of western Pacific tropical cyclone development during December 1996 – March 1997.

During northern winter the seasonal-mean convection in this region is organized into the ITCZ just south of the equator and the SPCZ east of Australia, with the former often influenced by low-level cross-equatorial flow from the north and the latter characterized by strong low-level cyclonic vorticity. Tropical cyclones often develop in these convergence zones. The large-scale transient motions include the Maddan-Julian Oscillation (MJO) from the equatorial Indian Ocean, the northeasterly cold surges from the northern hemisphere, and the synoptic-scale equatorial easterly waves propagating from the central or eastern Pacific. Previous studies (Liebmann et al, 1994) have shown that the development of the tropical cyclones tends to concentrate in the active phase region of the MJO. In this study we investigate the possible roles of MJO and the other transient large-scale motions in the development of the tropical storms during winter 1996/97.

The cold surge from the northern midlatitudes covered a wide longitudinal band of the subtropical northwestern Pacific. When a strong event approached the equator it tended to split into two branches, one in the South China Sea and the other east of Philippines and Borneo. The meridional wind at 7.5°N in the South China Sea was used as a surge index to identify these major events. A total of seven events were found, based on which the evolution of 1000 hPa winds from four days before to five days after the beginning of surges was composited. The results indicate that systematic large-scale changes in the southern tropics occurred as the surges developed, such that the low-level vorticity tended to intensify to the northwest of Australia and in the tropical vicinity of the SPCZ. This evolution made these two areas more favorable for tropical cyclogenesis during the strong surges.

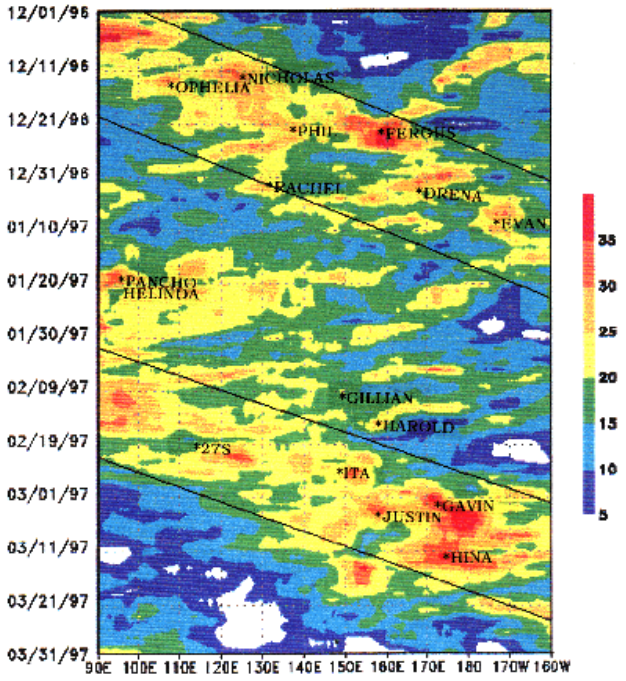
Two active phases of the MJO system moved across the region during the season. The first one started in the eastern Indian Ocean in early December and moved to the eastern Pacific in late December. The second one started in the eastern Indian Ocean in early February and moved to the eastern Pacific in early March. A total of 18 tropical storms formed between 18°S-10°N, with three in the northern

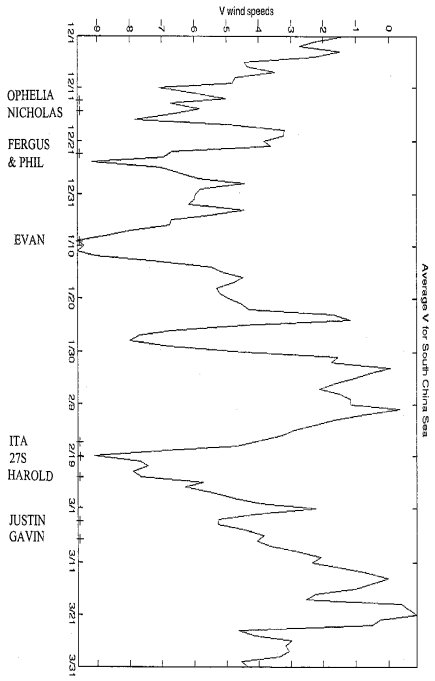
tropics and 15 in the southern tropics. As was reported by Liebmann et al 1994, most of these storms developed in or near the MJO super cloud clusters. However, most of the development also involved other motions systems, including the cold surge or the synoptic-scale easterly waves which propagated into the region from time to time on both sides of the equator.

Liebmann et al (1994) reported that more tropical cyclones developed in the active MJO areas not because of a higher percentage of development from tropical depressions, but rather because of the fact that more depressions existed in these convective areas. To examine the process leading to tropical depression enhancement, a pre-tropical storm formation center was defined when the maximum sustained wind of a tropical depression first reached 30 knots but still less than the definition for tropical storms. Based on this definition, it was determined that within the winter monsoon convection region, two of the three Northern Hemisphere pre-formations and 12 of the 14 Southern Hemisphere pre-formations occurred in the MJO. Of these, only one northern storm and two southern storms did not involve the cold surge or synoptic easterly waves. The most frequent occurrences involved the interaction of MJO and cold surges, followed by the interaction of MJO and easterly waves. In two cases all three systems were involved. Furthermore, both of the two southern storms developed outside of the active phase of MJO involved easterly waves, and one of them formed under cold surge conditions. It thus appeared that the active phase of MJO alone did not by itself give rise to most of the tropical storm formation. Rather, the cold surges from the northern hemisphere and the series of equatorial synoptic easterly waves propagating from the eastern or central Pacific provided additional mechanisms that caused most of the development.

The relationship between the tropical cyclone development and MJO and cold surges are illustrated in the figure in the next page. The left panel is a time-longitude section of the GMS satellite water vapor data with the position that a system first reaches 30 knots identified. The right panel shows the occurrence of these positions in a time section of the southern South China Sea surge index (averaged surface meridional wind at 7.5°N, 105°E-115°E).

The equatorial westerly burst and associated cross-equatorial flow have been shown to cause double-vortex formation in which a pair of cyclonic vortices straddle the equator and led to the development of twin cyclones, particularly near the dateline (e.g., Keen 1992; Ferreira et al. 1996). In the 1996-1997 season two short periods of double vortex configurations were found in the 1000 hPa wind field. The first occurred around 27-28 December and consisted of the northern tropical cyclone Fern and the southern tropical cyclone Fergus. However, close examination revealed that the two storms were formed in different processes, in particular Fergus was formed two days after Fern as a result of MJO active convection, a cold surge and an easterly wave. It was several days after both cyclones developed that they moved sufficiently close to result in a flow configuration of a northwest-southeast slanted double vortex. The other double vortex pattern occurred on 17 March after a complex evolution of the development of three tropical storms, Gavin, Justin and Hina, all of them in the southern tropics. Eventually Hina became the source of the southern equatorial vortex, and a weak northern circulation developed to its north but never reached a stage close to a tropical storm. Therefore, in both double vortex cases no cyclones were formed as a result of the MJO "double-vortex" mechanism.





2. Other activities during this year include the installation of the COAMPS model in the NPS and DoD computers, data preparation, and the coordination of post-field phase SCSMEX data analysis.

IMPACT

The research on the East and Southeast Asian monsoon disturbances provided better understanding of these heavy weather systems during the onset and active stages of the summer and winter monsoon. Understanding of the relationship between tropical cyclogenesis and large-scale tropical motions will help the prediction of tropical cyclone development with a longer lead time. Numerical experiments in simulating these disturbances will lead to better design of future modeling efforts. Continuous interaction with NRL scientists on the application of Navy models provided user feedback to the modelers on the model performance and special characteristics for the equatorial western Pacific, South and East China Sea, Japan Sea, Yellow Sea, eastern China, Japan and Korea region.

RELATED PROJECTS

1. Joint work with NSF Project on East Asian Monsoon at NPS. The NSF project conducted observational and theoretical studies of the Asian monsoon motions and complements the numerical modeling efforts of this project.

2. Collaboration with the NASA Scatterometer Project at JPL, P.I. Dr. W. Tim Liu. The JPL project provided the NSCAT data, technical assistance and programming support for running the NSCAT numerical experiment.

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